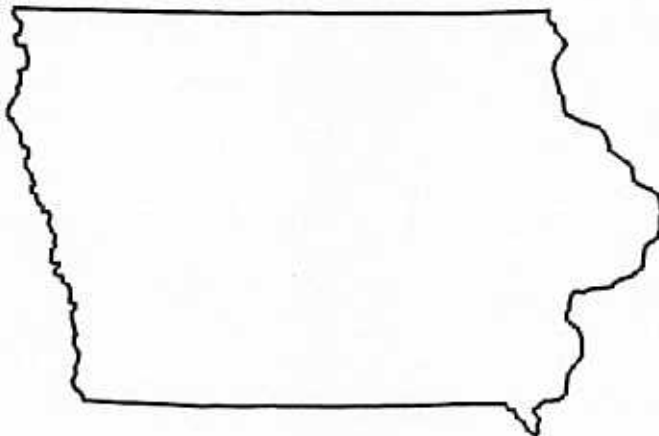


**U.S. Fish and Wildlife Service  
Region 3  
Contaminants Program**

**Herbicide and Algal Population  
Monitoring at  
DeSoto National Wildlife Refuge**

Study ID #: 3N14

by Tracy A. Copeland



**U.S. Fish and Wildlife Service  
4469 - 48th Avenue Court  
Rock Island, Illinois 61201  
June 1996**



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## **ABSTRACT**

Herbicide and water quality measurements were taken over two years in DeSoto Lake, Marquardt Pond and Young's Ditch on DeSoto National Wildlife Refuge. Previous studies had shown the presence of several herbicides in the surface waters of the refuge. This study was undertaken to determine if the concentrations present were harmful to fish and wildlife resources. Concentrations of herbicides detected, except for the drainage ditch, were less than U.S. Environmental Protection Agency maximum concentration levels or guidelines. There does not appear to be any direct adverse impacts to fish and wildlife resources from these chemicals, however, algal productivity may be suppressed by the presence of the herbicides.

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## **ACKNOWLEDGEMENTS**

Jennifer Kasuboski and Jim Huser were the technicians who did the majority of the sampling for this study. They were assisted by the 1993 Youth Conservation Corps members and summer interns from DeSoto National Wildlife Refuge. Terry Root, Mindy Sheets, and the rest of the refuge staff also assisted with site selection and technical assistance. The staff of the Steamship Bertrand Visitors' Center assisted with equipment and space. Lynn Hudachek and Jack Kennedy of the Iowa Hygienic Laboratory offered coordination assistance and technical support. Jody Millar offered editorial assistance and completed the final document. Sharon Gilliam again offered great word processing assistance. Thanks to everyone who assisted with this project.

# DESOTO NATIONAL WILDLIFE REFUGE

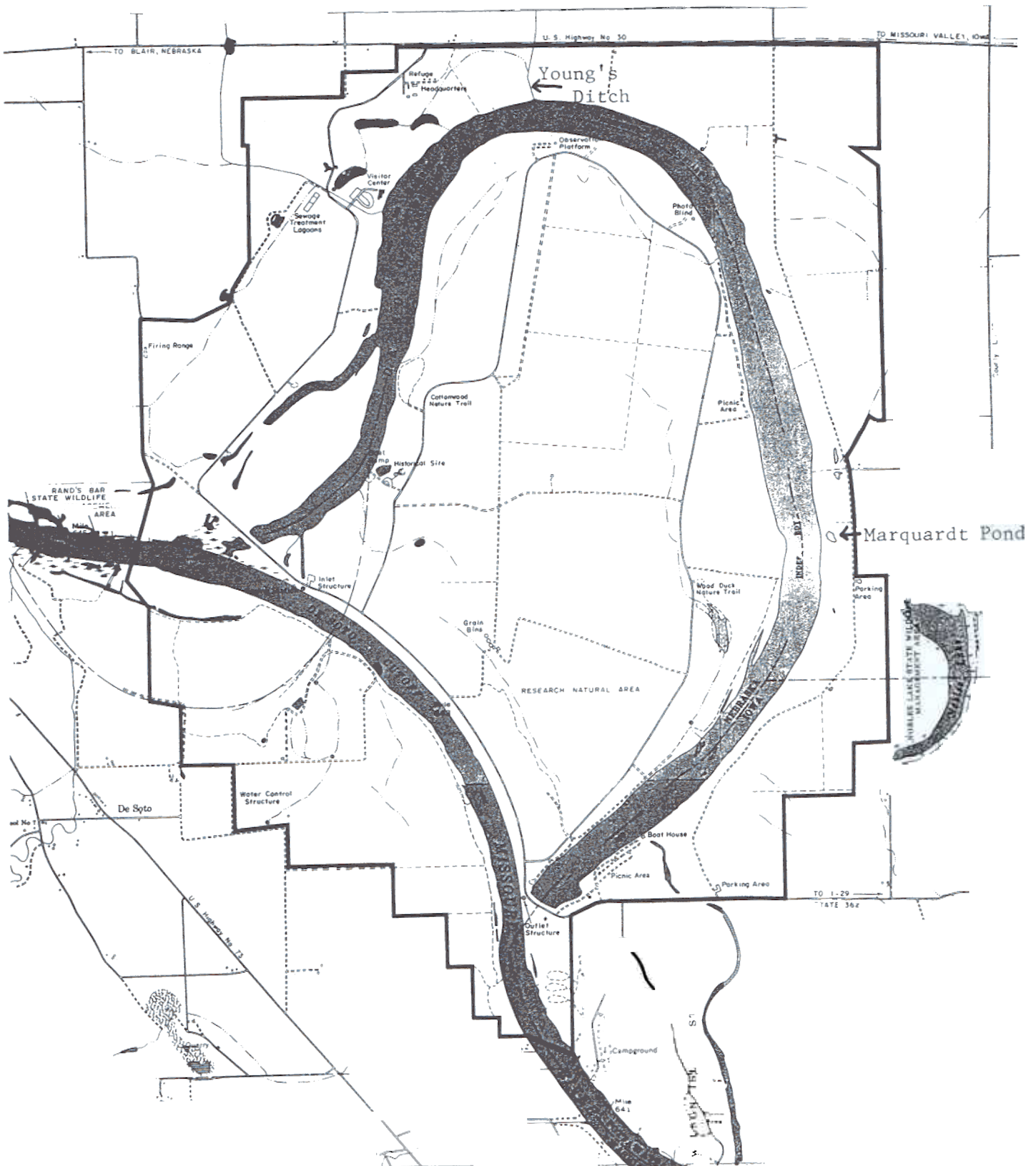


Figure DeSoto National Wildlife Refuge

## **INTRODUCTION**

A low-input cropping program was established in 1979 at the DeSoto National Wildlife Refuge. The integrated pest management program was introduced in 1988, and accomplishments monitored from 1988 through 1992 (Buske 1992). Integrated pest management uses a mixture of methods to control agricultural pests, including weeds and insects. Currently, the refuge has approximately 2300 acres of its total 7800 acres (29 percent) in crop production and is beginning to downsize this acreage to about 1500 - 1800 acres. At DeSoto, the common low input cropping technique is the use of a crop rotation system. The refuge also limits the use of herbicides, and avoids using insecticides.

Pesticide and fertilizer run off from refuge land to refuge surface waters has decreased with this program. The cooperative farmers use a rotation of corn and soybeans, with an alternating alfalfa or sweet clover and a small grain companion crop, in a three year cycle to control soil nutrient depletion. The application of nitrogen fertilizers is not permitted with the corn crop (Buske 1992).

Rather than widespread chemical use at recommended times, a crop scout is used to determine whether or not a pest is present, and if the intrusion economically warrants the purchase and application of herbicides. The refuge has not used chemical insecticides since the project inception; however, they have used several biological control measures, such as alfalfa weevil and corn borer parasites.

The project has had favorable results. Limiting the use of herbicides, and eliminating the use of insecticides has not had an adverse impact on crop yields. It has proven to be economically beneficial to the farmer. The yields are within normal ranges and money has been saved by avoiding needless, and expensive chemical applications.

From a natural resource perspective, the IPM program has also been beneficial. Migrating birds and wildlife are no longer exposed to the potential threat of primary or secondary impacts from pesticide use on the refuge. They have a diverse feeding area, and abundant protective cover available to them while using the refuge.

Because of all of these factors, and the fact that this program has been well planned and documented, the DeSoto project has national significance. It is being used as a prototype for other refuge IPM programs.

Past monitoring of the refuge surface water has identified three herbicides frequently present above standard detection limits. These herbicides are atrazine, cyanazine (Bladex) and metolachlor (Dual).

The Service maintains a list of herbicides which are approved for use on refuge lands. The three herbicides cited above are not on this pre-approved list, and are not known to be used. We have concluded that these chemicals are migrating to the refuge from beyond the refuge boundaries through runoff into agricultural drains. However, the impacts from agricultural chemicals used off refuge to wildlife which use the refuge had not yet been addressed.

### *Goals and Objectives*

The primary objective of this study was to determine if herbicides from off refuge sources impact algal communities in refuge surface water. A great deal of time and money has been spent monitoring the amounts of herbicides and nutrients in the soils and surface waters found within the refuge. However, impacts to biota have not been thoroughly examined.

During the mid-1980's DeSoto Lake was treated with rotenone to kill off its population of rough fish. Since that time, the lake has been restocked with sport fish, including northern pike and bass, and is now a popular fishing spot. A rapid die-off of algae can deplete the dissolved oxygen available for aquatic life. There have been recorded fish kills in DeSoto Lake, the causes of which were never clearly identified. This study attempted to determine if algal community die-offs may be related to increased concentrations of herbicides in the surface water.

The second objective of this study was to determine whether or not there are synergistic (additive) effects between these three chemicals on algal communities.

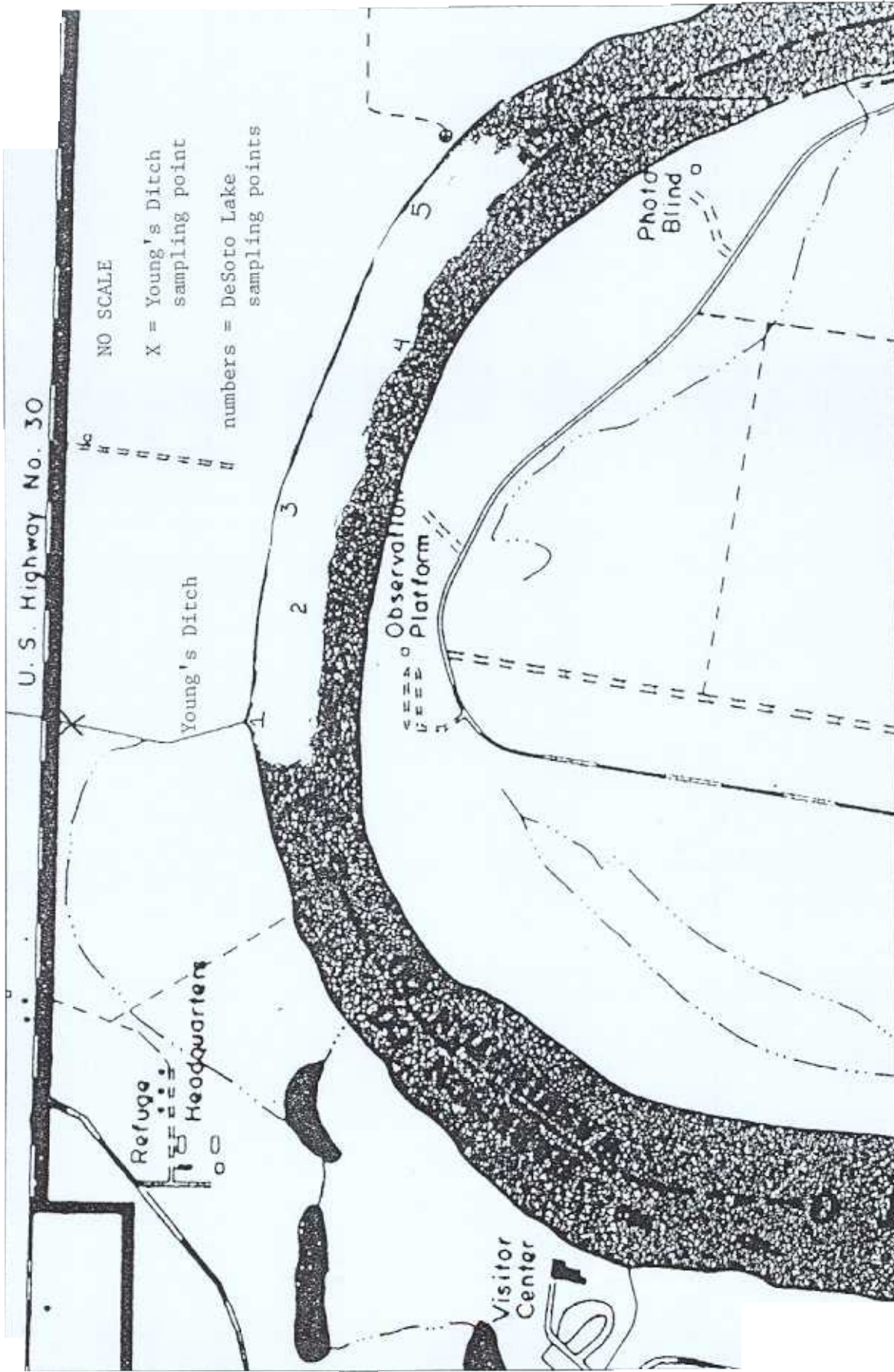


Figure 2. Map showing the detail of the sampling areas in DeSoto Lake and Young's Ditch.

Parking and boat staging area

NO SCALE

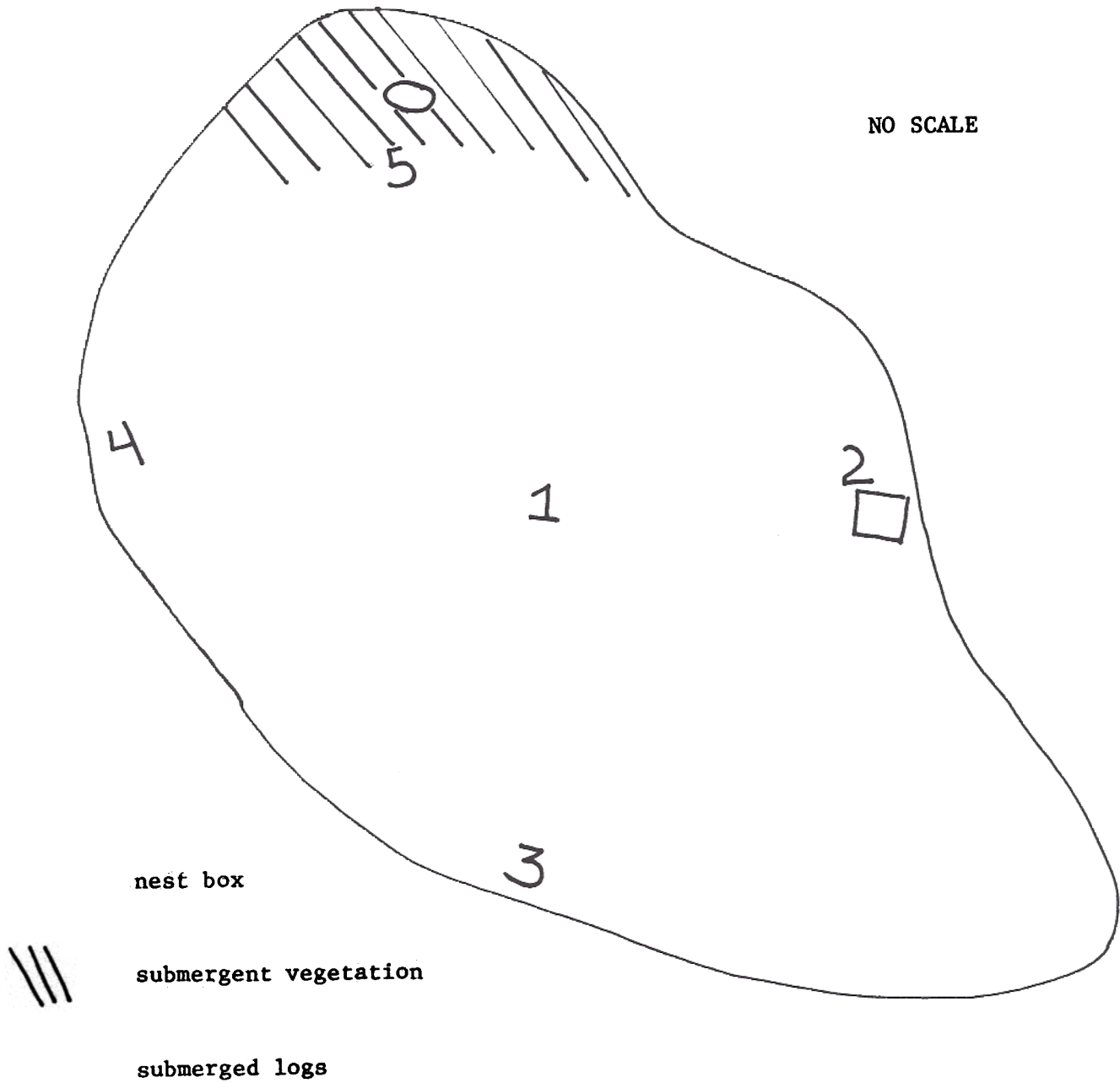


Figure 3. Map showing the detail of sample areas within Marquardt Pond.

## **SITE DESCRIPTIONS**

### ***DeSoto Lake***

DeSoto Lake is an oxbow of the Missouri River, located between river miles 641 and 645, in Harrison County, Iowa and Washington County, Nebraska. Currently only outlet structures connect the lake to the river proper. The 788-acre DeSoto Lake is the location of the steamship Bertrand which sunk in the 1860's, while travelling the Missouri up to the Dakotas. The remains of the steamship and its cargo may be seen at the refuge visitor center.

### ***Marquardt Pond***

Refuge personnel were asked to identify water bodies on the refuge which were isolated from drainage ditches and crop land. Marquardt Pond was selected as the control site. The one acre pond is located on the eastern boundary of the refuge. It has an extensive buffer strip of trees, shrubs, and grasses several hundred feet wide, encircling the entire pond.

Marquardt Pond is used by migrating birds, mammals, reptiles and amphibians. It has also been sporadically stocked with game fish.

### ***Young's Ditch***

The lake is fed by three large agricultural drainages. One of these, Young's Ditch, was the location of the water sampling sites for this study. During a cursory water quality evaluation, conducted in 1992, Young's Ditch consistently had the most elevated and varied concentrations of herbicides. Results of the 1992 water quality samples are presented in Table 1, Appendix A. Young's Ditch was chosen because this data seemed to indicate that this ditch was the most heavily compromised site along the lake. It enters DeSoto Lake after draining nine square miles (5760 acres) of non-refuge agricultural land, usually planted in common row crops.

## **METHODS**

### ***Sample Sites***

The three sites, described above, were selected for this study with the assistance of refuge personnel. Sites were selected based on

historical data and ease of access. Five sample locations were randomly dispersed throughout the area of the sampling sites, except for Young's Ditch. Only one site was sampled along the ditch.

Baseline samples were collected twice a month, one rainfall sample was to be collected each month, following a rainfall event of one inch or more, and a crash event sample was to be taken within 24 hours of the detection of an algae bloom die-off each month.

The first site was located in DeSoto Lake and is the impacted site, as it has direct input from non-refuge farm fields, through agricultural drains. An added benefit to this location is the availability of five years of water quality data, including herbicide concentrations. Five sampling locations were stretched from the mouth of Young's Ditch, east southeastward in the lake, over a 250 yard distance.

The second site, Marquardt Pond, is the control site. It is not connected through any drainage system to a farm field. The extensive buffer strip surrounding the pond would be expected to filter out many water quality contaminants from runoff. Although no historical water quality data exists for this waterbody, it was determined that the anticipated 'purity' of this system would be beneficial to the overall monitoring project. Because of its small size, sampling locations were spread throughout the pond. Samples were taken near shore and in the middle of the pond.

The control pond was to be sampled every time DeSoto Lake was sampled. However, because of access problems and time constraints encountered by the technician, this pond was sampled only four times in 1993. Rain washed access roads also affected the total number of samples collected in 1994, however the pond was then sampled nine times.

In 1994 Young's Ditch was added to the areas being sampled. This is the drainage ditch off of which the sampling in DeSoto Lake occurs. It was decided to add the agricultural ditch to the sampling regime to determine how much, if any, dilution of contaminants occurs in the surface water from where the ditch enters the refuge, to its discharge into DeSoto Lake. In 1994, seven samples were collected and analyzed from Young's Ditch.

### *Physical measurements*

Using standard equipment and meters, a technician took readings to determine the pH, dissolved oxygen, ambient water temperature and water transparency (Secchi disk reading). A Cole Parmer 59002 pH meter was used to take each reading, dissolved oxygen was taken with either a YSI or Garcia oxygen and temperature probe. All water temperatures were taken with the oxygen probe. Each meter was calibrated prior to each day's use.

### *Water sampling*

Water samples were also collected for analysis of seven common Iowa herbicides, ammonia nitrogen, organic nitrogen, total phosphorus (P), and total potassium (K). Water samples were collected using a clean glass jar. A capped jar was submerged to elbow depth and opened. The jar was allowed to fill with water before the cap was replaced. The full, sealed jar was lifted to the water surface and the water was apportioned into sample jars. These jars were supplied by the Hygienic Lab, which were prepared at the lab with fixatives.

A sulfuric acid fixative was used for samples to be analyzed for nitrogen compounds. A nitric acid preservative was used for non-nitrogen containing compounds. No preservatives were in the chlorophyll-a containers. The samples of water for herbicide analysis were not treated with a preservative in the field. Upon arrival at the laboratory, technicians poured the sample over a fixative. A total of 14 grab samples of water were analyzed from DeSoto Lake in 1993; 20 samples in 1994.

Chemical analysis was performed by the Iowa State Hygienic Laboratory, through coordination with Lynn Hudachek in Iowa City. The Hygienic Laboratory follows standard U.S. Environmental Protection Agency quality assurance and quality control measures when performing analyses.

The only variation to this sampling method was at Young's Ditch. Because of the location and difficult access, water was first collected from the ditch using a clean stainless steel pail. Sample jars for herbicide, chlorophyll, nitrogen compounds, potassium and phosphate were then removed from the pail.

### *Algae sampling*

A number 20 standard mesh plankton net was vertically dropped a maximum of ten feet at five stations in each sampling location. The site water was allowed to drain through the net, allowing the algae to collect in the closed end. Additional rinsing was done using clean tap water, and the net was rinsed from the outside.

The collected algae were decanted into a jar, for later identification and quantification, using tap or bottled water. In 1993 the algae samples were preserved with 70% ethanol, in 1994 the preservative used was Lugol's solution.

Algae were identified to division and genus if possible. The water sample was continuously stirred on a magnetic stand while a Hensen-Stemple pipette was used to extract a 1 ml random sample for counting purposes. A standard dissecting microscope or a standard laboratory microscope set to either 10 times or 43 times magnification was used to identify and count the sample.

### *Toxicity testing*

Toxicity testing was conducted by the Iowa Hygienic Laboratory. Testing was performed as outlined in Section 8111-Biostimulation, 18th Edition of Standard Methods.

Stock herbicide solutions were prepared by the Hygienic Lab Organic Section in Iowa City, Iowa. Concentrations examined were based on the average concentrations detected in DeSoto Lake and the drainage ditches in 1992, and were: atrazine 2.755 mg/L; Bladex 1.05 mg/L and Dual 3.39 mg/L.

To prepare a test concentration, for example 1 ml of atrazine stock and 1 ml of Bladex stock was added to a 1 liter volumetric flask and the flask filled to 1 liter with the algal medium and mixed. From this stock, 50 mls were transferred to ten 125 ml flasks using volumetric pipettes. A separate 1 liter flask and 50 ml volumetric pipette was used for each concentration. One additional 125 ml flask for each concentration was set up for dissolved oxygen and pH measurements. The remaining stock material was analyzed to confirm the actual

herbicide concentrations. The initial Iowa City stock herbicide concentrations were prepared in methanol. Thus, for the study controls, 3 ml of methanol was added to the 1 liter volumetric flask and mixed.

Each 125 ml flask was inoculated with 1000 cells of *Selenastrum capricornutum* and placed in an environmental chamber for 14 days at 24 +/- 2 °C under continuous cool-white lighting. Flasks were placed on a shaker table oscillating at 100 oscillations/minute. Temperature pH, dissolved oxygen and light intensity were recorded daily. Flasks were also randomly rotated about the shaker table each day. All flasks were stoppered with foam plugs to allow for gas exchange.

At the end of 14 days, 40 ml from each flask was removed and filtered through a pre-weighed filter. Filters were dried overnight in a drying oven and placed in a desiccator. Filters were then reweighed and weights recorded. Because weight loss can occur from the filters as liquids pass through, five filters were rinsed with solution containing no algae. These five filters had an average weight loss of 1.3 mg.

In 1994, the toxicity tests were altered slightly. The laboratory used a growth medium for the algae during the test. It was theorized that providing a growth medium, versus a nutrient void, would yield a better indication of impacted growth.

## RESULTS

### *DeSoto Lake*

Complete tabulated results of the herbicide and water quality analyses are presented in Tables 1 and 2 (Appendix A).

#### Herbicides

During a four month time period in 1993, atrazine, Bladex and Dual were detected in every sample collected in DeSoto Lake. The herbicide Lasso was detected in the samples collected during June and July. It was not detected in August or September.

During the 1994 sampling period, atrazine and Bladex were detected in every sample. Dual was detected in every sample, except those collected in late September. Lasso was detected in every June sample, and one July sample.

The 1993 concentrations of atrazine ranged from a high of 2.4  $\mu\text{g/L}$  in July to a low of 1.2  $\mu\text{g/L}$  in August. The atrazine metabolite desethyl atrazine was detected in every sample. Concentrations of desethyl atrazine ranged from 0.93  $\mu\text{g/L}$  in August to 0.24  $\mu\text{g/L}$  in July and July. The metabolite desisopropyl atrazine was detected during four of the seven 1993 sampling events. Concentrations of this metabolite ranged from 0.41  $\mu\text{g/L}$  to 0.25  $\mu\text{g/L}$ . Desisopropyl atrazine was not detected in any sample collected during June 1993.

During 1994, concentrations of atrazine ranged from 1.4  $\mu\text{g/L}$  in June to 0.89  $\mu\text{g/L}$  in September. The metabolite desethyl atrazine was also detected in every sample submitted. Concentrations ranged from 0.23  $\mu\text{g/L}$  in July to 0.12  $\mu\text{g/L}$  in June.

Bladex concentrations detected during 1993 ranged from a high of 2.9  $\mu\text{g/L}$  in June to 1.2  $\mu\text{g/L}$  in August. Dual ranged from a June high concentration of 1.8  $\mu\text{g/L}$  to a September low of 0.14  $\mu\text{g/L}$ . Lasso was detected during June and July only. The highest concentration of this herbicide was 1.7  $\mu\text{g/L}$ , with a July 28 low of 0.16  $\mu\text{g/L}$ .

1994 concentrations of Bladex ranged from 1.1  $\mu\text{g/L}$  to 0.55  $\mu\text{g/L}$ , while Dual ranged from not detectable above 0.1  $\mu\text{g/L}$  to 0.85  $\mu\text{g/L}$ . Lasso was detected in June and July with concentrations from 0.18  $\mu\text{g/L}$  to 0.11  $\mu\text{g/L}$ .

Three other common Iowa herbicides, Sencor, Sutan, and Treflan were not present above the standard detection limit of 0.1  $\mu\text{g/L}$  during either sampling year.

#### Water quality

In 1993, corrected chlorophyll *a* readings, a measure of biomass and productivity, showed an overall increase during the sampling period of June through September. There were three instances of minor fall offs; one in June and two in July. There was a steady increase in *chlorophyll a* production from August through September.

In 1994, there were also three minor decreases in *chlorophyll a* production. These occurred in June, July and August. By the end of the sampling period, *chlorophyll a* production was just beginning to decrease for the fourth time.

Organic nitrogen readings, in 1993, ranged from below a detection limit of 0.1 mg/l to 2.8 mg/l. The highest readings occurred in September and the lowest in June. Ammonia nitrogen, during this same sample period ranged from 0.1 to 0.4 mg/l.

In 1994, there were only four nitrate plus nitrite measurements above the detection limit of 0.1 mg/l. Three of these four readings occurred in June, while a 0.1 mg/l measurement was made in September. The highest of these measurements was 0.4 mg/l and occurred in June. Ammonia nitrogen in 1994 ranged from <0.1 mg/l to 1.1 mg/l.

Total phosphate averaged 0.1 mg/l in 1993. The highest concentration detected was 0.3 mg/l in June. This element was not detected during July 1993. In 1994 total phosphate again averaged about 0.1 mg/l. The element was, however, detected during each month.

Total potassium averaged 7.8 mg/l in 1993. This nutrient had concentrations ranging from 7.0 to 8.9 mg/l, with the highest concentration occurring in September. In 1994 this element averaged 7.25 mg/l, with a low measurement of 1.5 mg/l recorded at one site in August.

In 1993 the average pH of DeSoto Lake was 9.21. In 1994, pH averaged 8.58. Dissolved oxygen averaged 7.8 mg/l in 1993, with a low reading of 4.6 mg/l in June. In 1994 the lowest dissolved oxygen reading was 6.6 mg/l, recorded in June and July, with an average of 8.84 mg/l during the sample period.

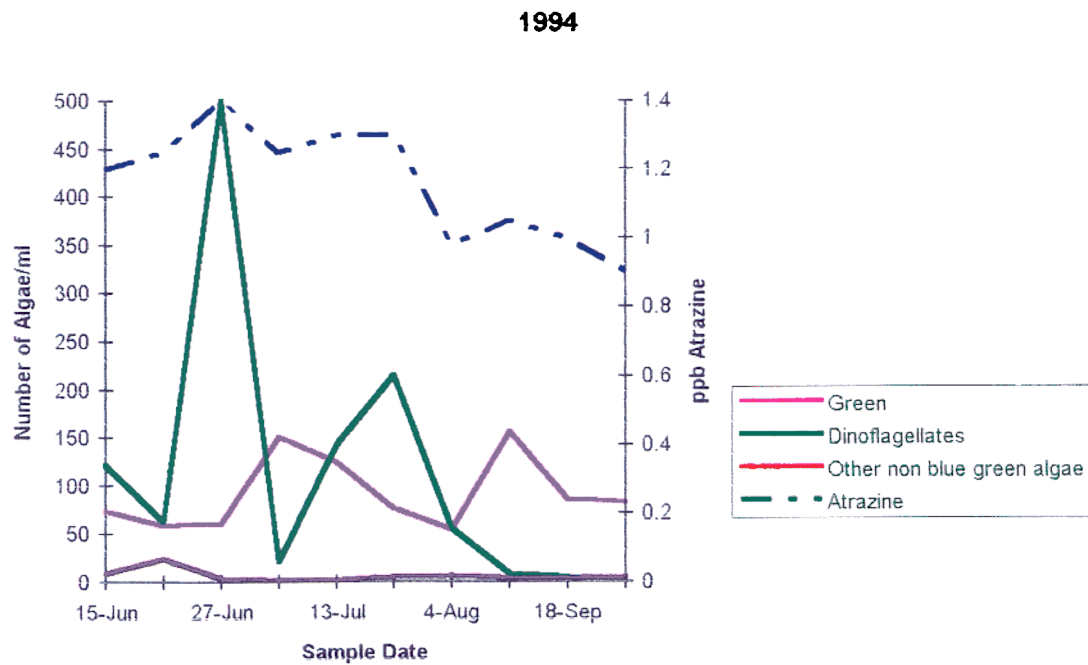
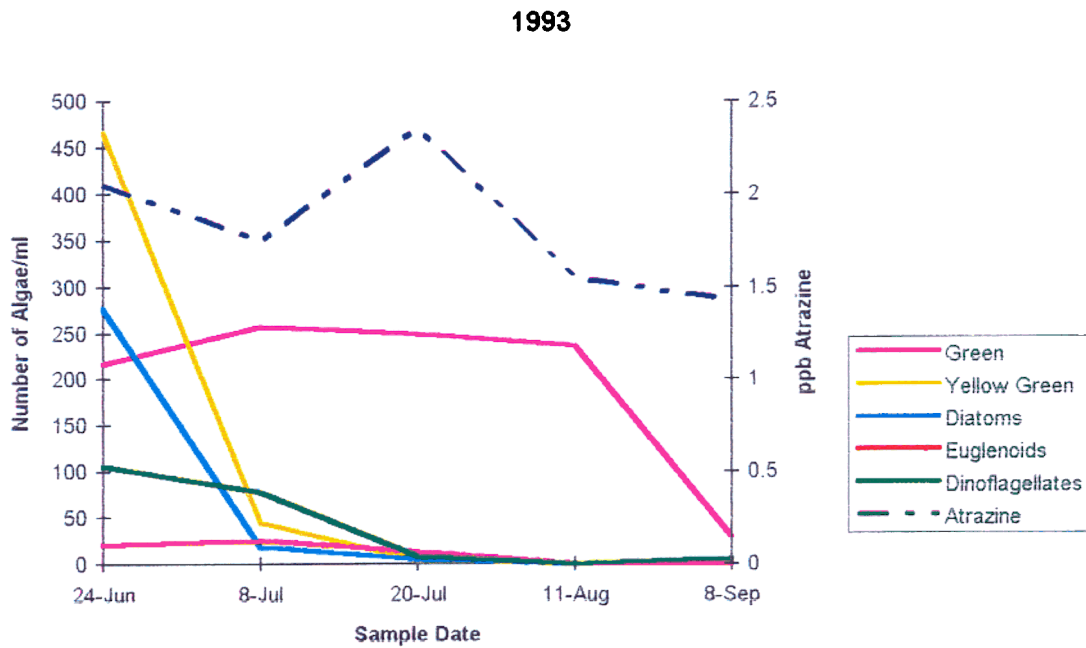
#### Algal populations

During 1993, blue green algae present in DeSoto Lake were considered too numerous to count. This was due to the presence of abundant *Aphanizomenon*. Green algae, predominantly *Ulothrix* and *Pediastrum*, remained constant throughout the summer, but in early September had a large decrease in numbers. Yellow-green algae (*Chrysophyta*) were present from June through July, but were not found during August and September. Diatoms were recorded in June, July and September, with the largest concentration occurring in June. Euglenoids were detected only in June and July. Dinoflagellates were detected in moderate numbers during June and early July; in low numbers in late July and September. Euglenoids were not detected during August.

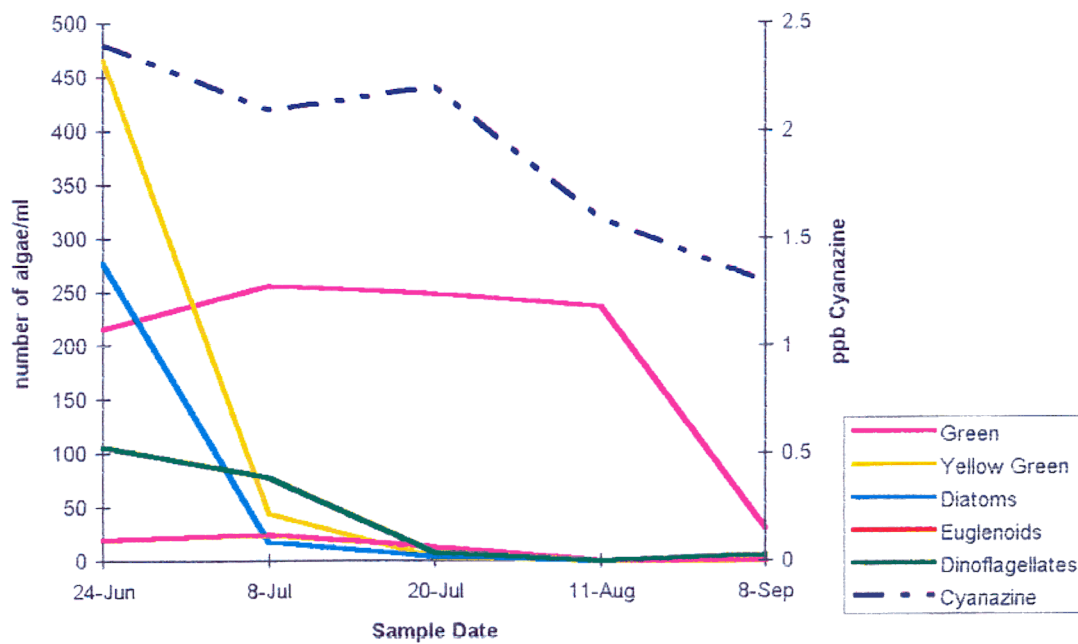
Blue green algae were too numerous to count in 1994 as well. However, in addition to large numbers of *Aphanizomenon*, several other blue green algae were recorded. These included *Microcystis*, *Oscillatoria*, and *Anabaena*.

*Chlorophyta* (green algae) were present in each sample. The highest concentrations during 1994 occurred during July and August. Small numbers of yellow-green algae were detected in each month, as were diatoms and euglenoids. Dinoflagellates (*Pyrrhophyta*) were detected each month with the highest concentrations occurring in late June and mid-July.

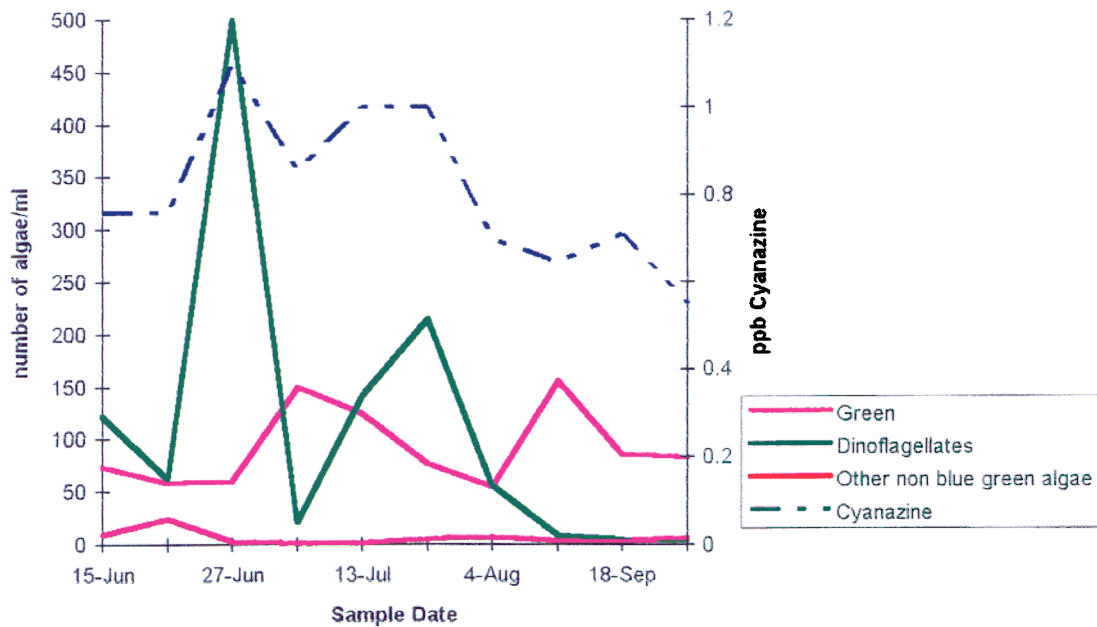
Results of algal populations and herbicide concentrations are presented in Figures 4, 5 and 6.



**Figure 4.** Populations of algae, excluding blue-greens, and concentrations of atrazine detected in DeSoto Lake, 1993 and 1994, DeSoto National Wildlife Refuge.

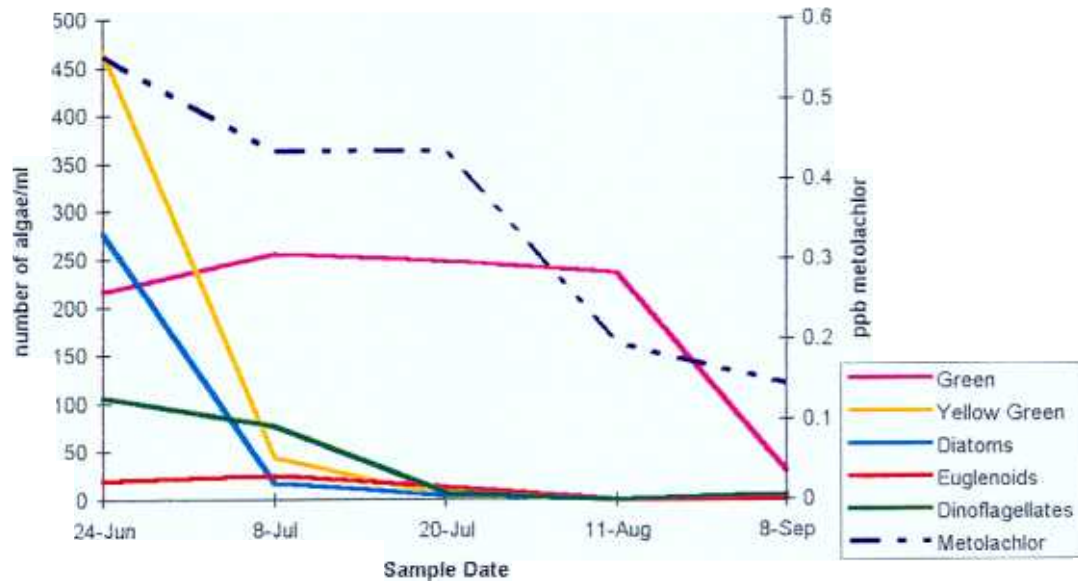


1994



**Figure 5. Populations of algae, excluding blue greens, and concentrations of cyanazine detected in DeSoto Lake, 1993 and 1994, DeSoto National Wildlife Refuge.**

1993



1994

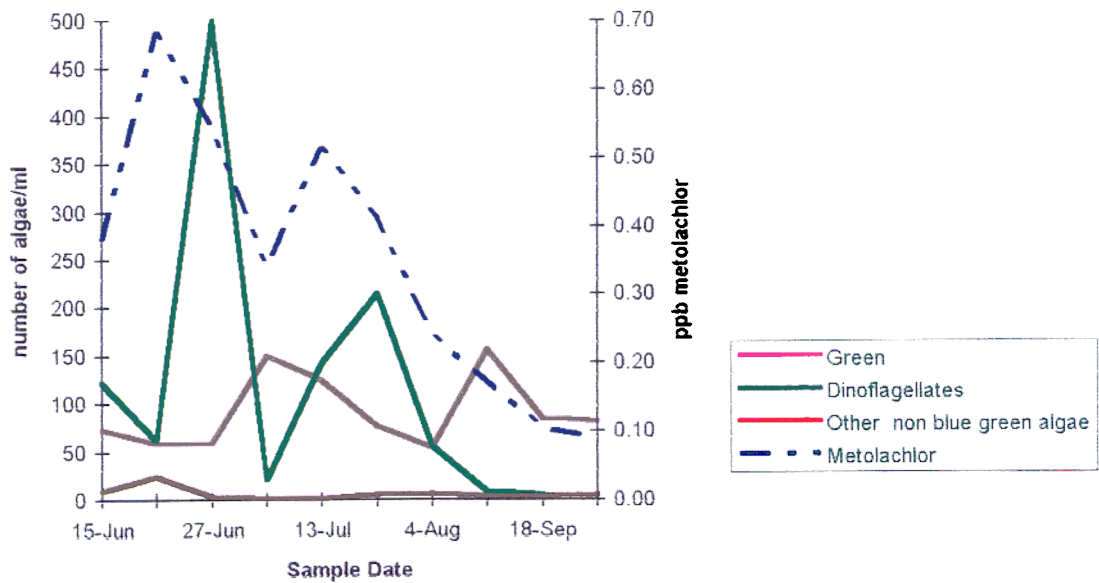


Figure 6. Populations of algae, excluding blue greens, and concentrations of metolachlor detected in DeSoto Lake, 1993 and 1994, DeSoto National Wildlife Refuge.

## ***Marquardt Pond***

Results of the herbicide and water quality analyses for Marquardt Pond are presented in Tables 3 and 4 (Appendix B).

### **Herbicides**

Marquardt Pond was sampled both in 1993 and 1994 as a control site. During the 1993 sample period no herbicides, or herbicide metabolites were detected in the pond above the standard detection limit of 0.1  $\mu\text{g/L}$ .

During 1994 both atrazine and Bladex were detected in this control site. Atrazine was detected in both June and July at concentrations of 0.1 to 0.11  $\mu\text{g/L}$ . Bladex was also detected in June and July with concentrations ranging from 0.1 to 0.12  $\mu\text{g/L}$ . No other herbicide or metabolite was detected above the 0.1  $\mu\text{g/L}$  standard detection limit.

### **Water quality**

Corrected chlorophyll a, in 1993 indicated minimal production in June, and moderate production in July. There was a slight decrease in biomass production in August. The highest measurements of chlorophyll a production occurred during the last sampling event of 1993, in September.

In 1994, chlorophyll a production was below the detection limit of 1.0  $\mu\text{g/l}$  throughout June. There was slight production in July. Highest productivity was recorded in August, with a drop off during early September. By the last sampling event, chlorophyll a production was beginning to rise again.

Organic nitrogen in 1993 was measured at an average of 1.1 mg/L in Marquardt Pond. The concentrations ranged from 0.7 mg/L in June to 1.7 mg/L in September. Organic nitrogen was not consistently measured during 1994.

Ammonia nitrogen in 1993 averaged 0.1 mg/L. This nutrient was not detected in Marquardt during the months of June and July. In 1994 ammonia nitrogen was detected at an average of 0.26 mg/L, with a peak value of 0.9 mg/L detected in June.

Nitrate and nitrite nitrogen was detected only during June 1994, a measurement of 0.2 mg/L was taken.

Total phosphate was measured at an average of 0.1 mg/L in Marquardt Pond during 1993. This element was not detected during July and August. In 1994, phosphate was detected in only six of 20 samples. The highest concentration measured was 0.2 mg/L in June.

In 1993, the element potassium was detected in Marquardt Pond at an average concentration of 9.05 mg/L. The lowest detection amount of the nutrient was 2.9 mg/L in June. The 1994 average potassium concentration was 7.91, the lowest reading of 1.9 mg/L occurred in August.

The pH of Marquardt Pond averaged 9.0 in 1993 and 8.22 in 1994. Dissolved oxygen averaged 3.9 mg/l in 1993, with a low reading of 0.3 mg/l occurring in both August and September. In 1994, dissolved oxygen averaged 4.7 mg/l, with low readings of 0.9 mg/l recorded in August.

#### Algal populations

During 1993 algae collections were not identified or enumerated during June. In July there were small numbers of blue green algae, *Aphanizomenon* and *Spirulina*; and green algae, *Volvox*. A moderate number of yellow green algae, *Dinobryon*, were detected in July. The most dominant division of algae identified in July were the dinoflagellates, mostly *Ceratium*.

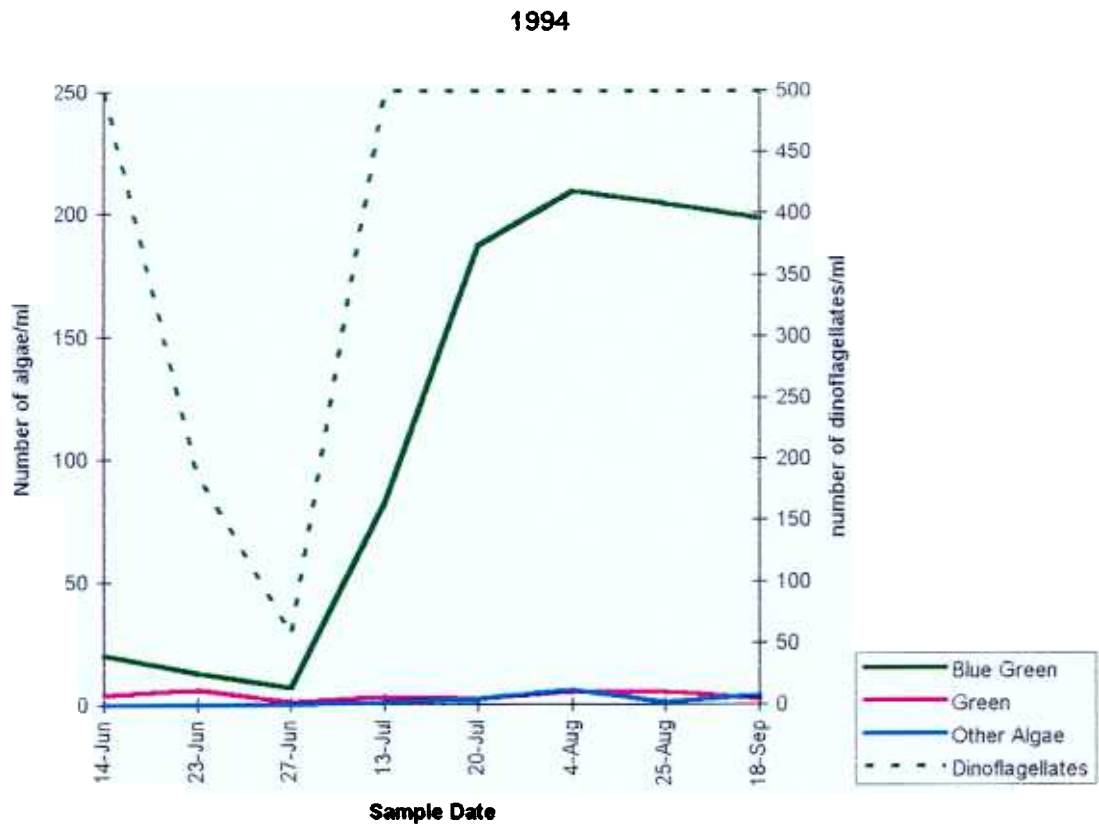
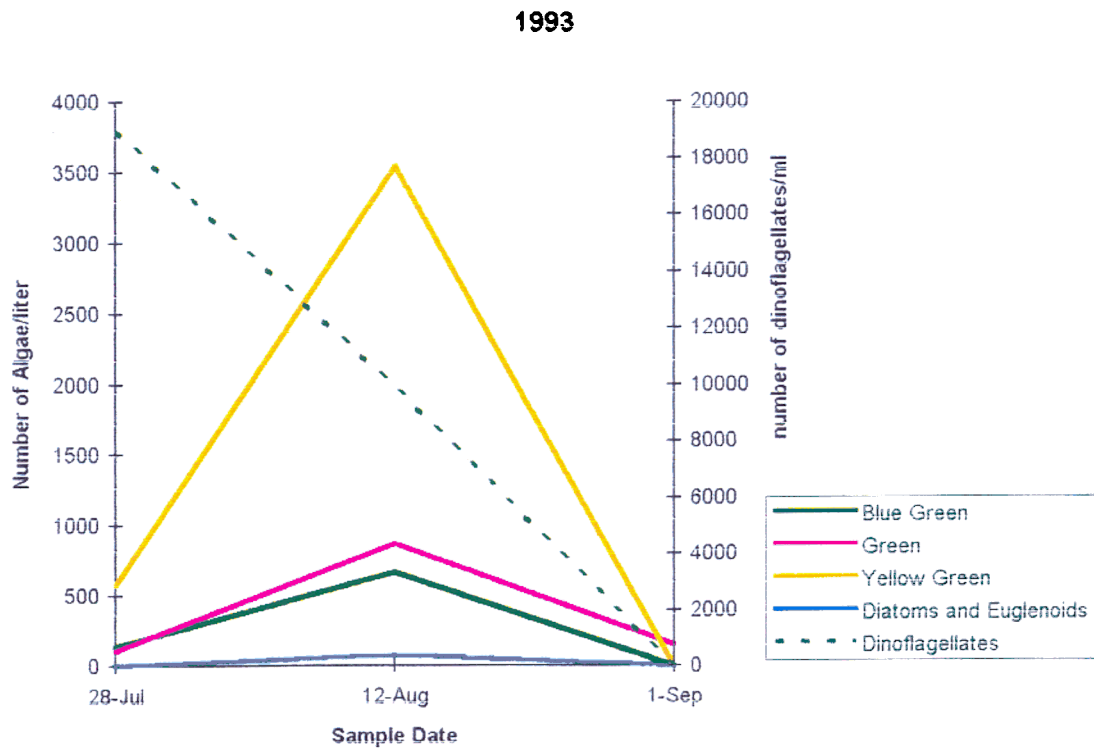
In August there was a marked increase in blue-greens, green and yellow green algae. Diatoms and euglenoids were also detected in very low numbers. The July dinoflagellate bloom decreased by approximately half in August. Only green algae, *Volvox*, were detected in September in Marquardt Pond.

The 1994 analysis of the algae collections indicate a continual bloom of dinoflagellates, consisting of *Ceratium*. This bloom decreased slightly in late June, but continued to be too numerous to count until late September.

Blue-green algae were present throughout the sampling season, with the largest populations occurring in August. Typical representatives of this division were *Anabaena*, *Microcystis*, *Aphanizomenon*, and *Oscillatoria*.

Small numbers of *Volvox*, *Ulothrix*, and *Pediastrum*, represented the green algae throughout the sample months. *Chrysophyta* (yellow-green) appeared in September. Diatoms did not appear in the samples until August, and then only in small amounts. Small numbers of euglenoids also showed up in the samples beginning in July.

Algal populations are presented in graph form as Figure 7.



**Figure 7. Populations of algae detected in Marquardt Pond, 1993 and 1994, DeSoto National Wildlife Refuge.**

## *Young's Ditch*

Results of the herbicide and water quality analyses for Young's Ditch are presented in Table 5 (Appendix C).

### Herbicides

Four herbicides were detected in the surface water of Young's Ditch during the 1994 sampling period. The ditch was not sampled during 1993.

Atrazine was found in each sample. Concentrations ranged from 0.68  $\mu\text{g/L}$  in July, to 5.0  $\mu\text{g/L}$  in June, following a one inch rainfall. Bladex was detected in five of the seven samples. Concentrations ranged from  $<0.1$   $\mu\text{g/L}$  in July to 2.0  $\mu\text{g/L}$  in June.

Dual was detected in each month except September. The highest concentrations occurred in June at 11  $\mu\text{g/L}$ . Lasso was also detected in each month except late August and September. The highest concentration of this herbicide was 1.1  $\mu\text{g/L}$ .

### Water quality

Corrected chlorophyll a indicated low biomass production in June and early July. Production peaked in early August, before dropping back in September. A chart of this biomass production is presented in Figure 8.

Ammonia nitrogen ranged from  $< 0.1$  mg/L to 0.6 mg/L. The peak occurred in June, following a one inch rainfall event. Nitrate and nitrite nitrogen ranged from  $<0.1$  mg/L to 6.4 mg/L. Again the peak concentration occurred in June, following rainfall.

Total phosphate averaged 0.31 mg/L in Young's Ditch during 1994. Concentrations ranged from 0.1 to 0.6 mg/L. Potassium averaged 9.4 mg/L. This nutrient had a range of 6.4 to 12 mg/L, with the peak occurring in early August.

The pH of the drainage ditch averaged 7.7. The range recorded was 7.43 to 8.16. Dissolved oxygen ranged from 3.2 mg/l to 8.7 mg/L, with the peak occurring in July. The average water temperature for this site during 1994 was 22.7 °C.

### Algal populations

Blue-green algae were detected in the ditch during each month. In August and September, due to the presence of *Microcystis*, *Aphanizomenon*, and *Oscillatoria* the numbers of algae were too numerous to count. There were also high concentrations of *Microcystis* occurring in June and late July.

Small amounts of green algae, predominantly *Ulothrix*, with some *Spirogyra*, were found in each month. Few representatives of the yellow-green algae, diatoms and euglenoid were detected in July and August. Very few of the dinoflagellate *Ceratium* were only recorded during June and July.

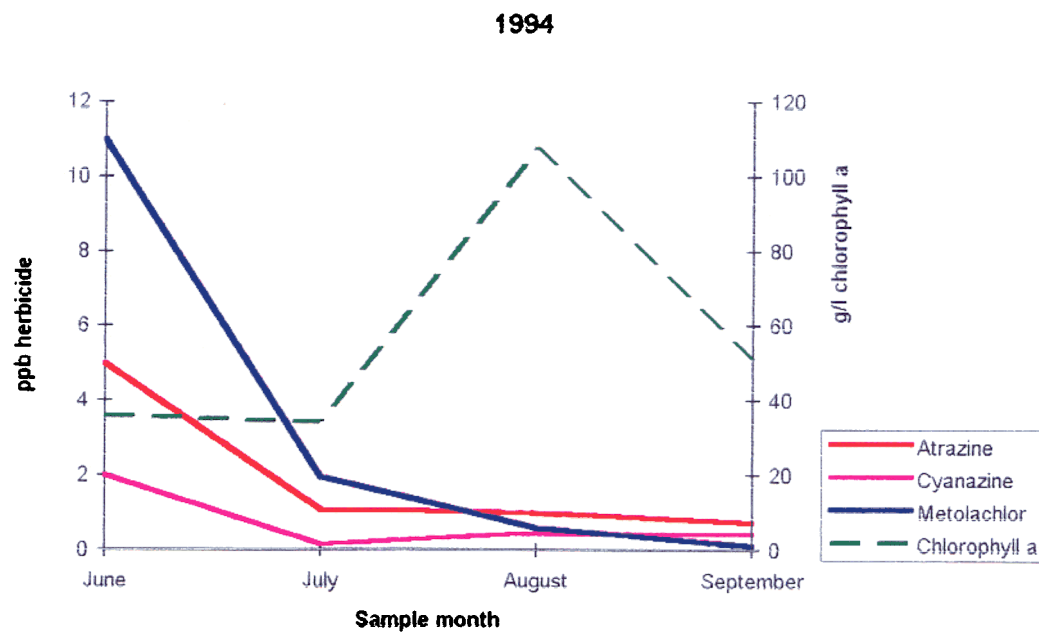


Figure 8. Average corrected *chlorophyll a* measurements in Young's Ditch, 1994, DeSoto National Wildlife Refuge

### *Toxicity tests*

Kruskal Wallace one way analysis of variance for non-parametric data calculations are presented in Appendix D (Zar 1984; Normal and Streiner 1994). Completion of the Kruskal Wallace calculations indicated that there was a significant difference in *Selenastrum* growth undergoing different herbicide treatments, when compared to an untreated control.

The application of a Tukey type comparison (Zar 1984) indicated that there was a variation among all of the treatment groups. It was not possible to evaluate the synergy, or lack thereof, of these mixtures based on these results.

## DISCUSSION

### *Herbicides*

#### Atrazine

Atrazine is a colorless crystal member of the triazine family of herbicides. It is relatively insoluble, with a solubility of 33 ppm in water, and is used as a season long selective herbicide on corn, sorghum and other crops (Farm Chemical Handbook 1995).

It's herbicidal properties were discovered in the early 1950's, and it was introduced as an herbicide in the United States in 1958 (Sassman, et. al. 1984). In addition to the uses listed above, atrazine has previously been registered for use on forest lands and for nonselective control on noncrop lands (Sassman, et. al. 1984).

Atrazine is probably the most commonly used herbicide in the country today. An estimated 58.1 million pounds of atrazine were applied to 64 percent of the total corn acreage planted in the United States in 1990 - 47.7 million treated acres (Ciba Plant Protection 1993). Most of the U.S. corn production occurs in the midwest. Iowa alone, in 1990, had 12.8 million acres planted to corn (Ciba Plant Protection 1993).

This herbicide was detected in DeSoto Lake in 1993, at a peak concentration of 2.4 ppb. In 1994 the peak concentration of this herbicide in DeSoto Lake decreased to 1.4 ppb. Based upon the presence of its metabolites, in measurable concentrations, atrazine is appears to be present continuously in this lake.

Marquardt Pond had no detectable concentrations of atrazine in 1993, however, in June and July of 1994, the herbicide was detected just above the detection limit with a concentrations 0.11 ppb. No metabolites were present in the pond, leading to the assumption that the lower concentrations of atrazine detected do not yield measurable quantities of metabolites.

Young's Ditch was not surveyed in 1993, however in 1994 a peak concentration of 5.0 ppb was detected just below the Highway 30 bridge. This is substantially higher than the concentration of 2.9 ppb detected in the ditch during July 1992.

The U.S. EPA has set a maximum contaminant level of 3.0 ppb in drinking water for this herbicide, and has classified it as a possible human carcinogen (Table 7). These MCLs are for the protection of human health. Other than the peak concentration detected in Young's Ditch, no concentrations were detected in excess of this limit. Currently, there are no atrazine standards in place for the protection of human health or aquatic life in ambient surface waters.

### Cyanazine

Cyanazine is a non-persistent selective herbicide. Related to atrazine, this member of the triazine family is a white crystalline solid.

This compound is registered for early pre-plant, pre or post-emergent use on corn or cotton, and may be sold under the trade name Bladex (Farm Chemicals Handbook 1995). As stated previously, Iowa is a major producer of corn in the mid-west, and cyanazine or cyanazine containing mixtures are commonly applied by area producers.

This herbicide readily adsorbs to soils, but the process can be reversed depending upon water, pH and temperature conditions. Past tests have indicated that cyanazine will leach through almost five inches of soil with the application of two inches of water. Under optimal growing conditions, cyanazine has a half life of two weeks and is broken down by soil microbes (Herbicide Handbook 1983).

Cyanazine was detected in every sample collected from DeSoto Lake in both 1993 and 1994. A peak concentration of 2.9 ppb occurred in June of 1993. By 1994 the peak concentration had declined to 1.1

ppb and this occurred in both June and July. This herbicide was not detected in Marquardt Pond during 1993, however, concentrations ranging from 0.1 to 0.12 ppb were detected during the month of June, 1994. Peak concentrations of cyanazine in Young's Ditch occurred during July, 1992 and June, 1994 - both at 2.0 ppb.

US EPA has designated cyanazine as a possible human carcinogen, and has set a non-regulatory maximum contaminant level guideline of 0.001 ppm (Table 7). There are no criteria established, at this time, for the protection of human health or aquatic life in surface waters.

Table 7. US EPA Drinking Water Standards for the Protection of Human Health (mg/L) and Related Carcinogenicity.			
Herbicide	MCL	MCLG	Carcinogenicity
Alachlor	0.002	0	probable human carcinogen at 0.083 mg/kg/day (animal tests)
Atrazine	0.003	0.003	possible human carcinogen at 0.22 mg/kg/day
Cyanazine	no standard reported	0.001	possible human carcinogen at 0.84 mg/kg/day
Metolachlor	no standard reported	no standard reported	possible human carcinogen at 0.0020 mg/kg/day

MCL = maximum contaminant level (regulatory)

MCLG = maximum contaminant level guideline (non-regulatory)

(from Nowel and Resek 1994)

### Metolachlor

Metolachlor, sold under the trade name Dual, is a white to tan liquid of the chloracetanilide family of herbicides. It is a selective herbicide registered for pre-emergent and pre-plant application to corn, soybeans, peanuts, other crops and woody ornamentals (Farm Chemicals Handbook 1995).

Metolachlor is easily adsorbed to soils with a high organic and clay content. While it can be moved with soil particles, no significant leaching of metolachlor is expected to occur when soil organic content approaches two percent (Herbicide Handbook 1983). This non-persistent herbicide has a half life of eight days under natural lighting conditions.

In addition to being a major corn producer, Iowa is also a leading producer of soybeans. In 1990 there were 8.3 million acres planted to soybean in the state of Iowa - almost 14% of the national total. Nationwide 9.8 million pounds of metolachlor were applied to 5.6 million acres of soybean; and 35.9 million pounds of this herbicide were applied to 19.2 million acres of corn nationwide (Ciba Plant Protection 1993).

Metolachlor was detected in DeSoto Lake during each sample year of this study. In 1993 peak concentrations occurred in June at 1.8 ppb, and in 1994 the peak concentration detected was 0.85 ppb, also in June.

This herbicide was not detected in Marquardt Pond during either sample year, while a peak concentration of 11 ppb occurred in Young's Ditch in June 1994, substantially higher than the July peak of 4.1 ppb in 1992.

The US EPA has identified this herbicide as a possible carcinogen, but no drinking water standards or guidelines have been established for the protection of human health (Table 7). As with atrazine and cyanazine no surface water standards have been established for either the protection of human health or aquatic life.

### Alachlor

Alachlor is a colorless crystal member of the acetanilide family of herbicides. It is sold under the trade name Lasso, and is registered for pre-emergent use in corn, dry bean, peanuts and soybeans (Farm Chemicals Handbook 1995).

This herbicide is rapidly metabolized by plants. Alachlor adsorbs to soil colloids and is readily broken down by soil microbes. The herbicide is non-persistent to moderately persistent, with a six to ten week half-life (Herbicide Handbook 1983).

A peak concentration of 1.7 ppb of alachlor was detected in DeSoto Lake during June 1993. A significant decline in the presence of this herbicide was seen in DeSoto Lake during 1994, when a peak concentration of 0.18 ppb was detected in June. Lasso was not detected in Marquardt Pond during either study year. A peak concentration of 1.1 ppb was detected in Young's Ditch during 1994, exceeding the peak of 0.21 ppb detected in the same ditch during 1992.

The US EPA has established a maximum contaminant level of 0.002 mg/L for this compound in drinking water. It has also been identified as a probable human carcinogen (Table 7). No criteria have been established for this compound in ambient surface water.

### *Algae populations*

Algae are photosynthetic, non-vascular plants, which include some of the most primitive plants known today. There are many variations of algae, which may occur as single cells, colonies and filaments. In addition to photosynthesis, algae also obtain water and nutrients directly from their surroundings. Algae are the major primary producers in aquatic environments (Rost et.al. 1979).

As nutrients increase, so does algal productivity. This increased productivity leads to more turbid water and lower light penetration. As pond eutrophication occurs, algae replace each other. In most cases, green algae will be replaced by blue-greens, as blue-greens appear to be more tolerant of low water quality and human induced pollution.

While algae are important ecologically, the presence of large numbers of these plant organisms can severely deplete the oxygen found in aquatic ecosystems. The depletion of oxygen will then lead to a loss of diversity of higher forms of plant and animal life.

### Blue-green algae

Blue green algae, known as *Cyanophyta*, are considered closely related to bacteria in structure, and may also be known as *Cyanobacteria*. This division of algae contains *chlorophyll a* and may appear to tint the water in which they are found a blueish green color (Rost et. al. 1979).

The *Cyanophyta* are the organisms which give off foul smelling odors and bad tastes in polluted waters. Their numbers increase during the eutrophication process, and they appear to be more tolerant of pollution and nutrient enrichment.

During this study, DeSoto Lake maintained a large population of blue-green algae, considered too numerous to count during the process of enumeration. This is not considered unusual when one considers the

various inputs into the lake, as well as its past history of being a oxbow of the Missouri River. The presence of a substantial amount of blue-green algae also explains the greenish color of this lake.

Marquardt Pond is a smaller body of water, not as advanced in the eutrophication process as DeSoto Lake. It is a deep pond, yet is extremely clear. This pond has limited inputs from nutrients and chemicals, since it is surrounded by a substantial vegetated buffer zone. When compared to DeSoto Lake, the numbers of blue-green algae detected in Marquardt Pond were minimal (refer to Figures 4 through 7).

The turbid waters of Young's Ditch had low algal production during the early summer. However in August the numbers of blue green algae exploded to the point where the technicians could not count them.

#### Green algae

Green algae, or *Chlorophyta*, occur predominantly in fresh water - although they may also be found in salt water, snow and hot springs. These organisms contain both *chlorophyll a* and *b*.

The *Chlorophyta*, while being the second largest division of algae are not very tolerant of changes in the water quality. For this reason, during the eutrophication process, the green algae are often displaced by blue-green.

During the sampling of DeSoto Lake, the numbers of green algae increase from late spring to mid summer. This is a normal succession based on the availability of a food source, light and temperature. However, in both years, this division of algae was substantially lower in numbers than the blue-greens.

Marquardt Pond showed a similar trend with respect to this division, as did the drainage ditch.

#### Diatoms and dinoflagellates

The diatoms (*Bacillariophyta*) and dinoflagellates (*Pyrrophyta*) dominate the phytoplankton divisions. Both groups are not very tolerant of high nutrient levels or pollution. During normal succession, they tend to occur early in the year, being replaced by green algae as waters warm and food sources vary.

In both DeSoto Lake and Marquardt Pond, during 1994, dinoflagellates dominated the non-blue green algae. The reason for this domination remains unclear. Very few of these organisms were detected in Young's Ditch during that sample year.

### *Toxicity tests*

Toxicity tests are generally use mortality as an endpoint to demonstrate toxic effects of a condition or substance. The test used in this study was a measurement of biomass production, not mortality. The test used - 8111 Biostimulation algal productivity (Standard Methods 1992)- is beneficial in determining the response of algae to water quality.

As expected, the presence of atrazine, cyanazine and metolachlor appears to adversely affect green algae production. The test was inconclusive in determining whether or not the effects of these chemicals are enhanced when they are mixed together.

Effects of herbicide mixtures and herbicide/insecticide mixtures have been proven to cause adverse effects to algal community structure. However most literature appears to use concentrations of atrazine, cyanazine or metolachlor in excess of 50 ppb. The concentrations used in this trial were consistent with the concentrations detected in the lake during 1992, and were well below 5 ppb. More work will be needed to determine if the mixtures of the chemicals at these concentrations are harmful to fish and wildlife.

### **CONCLUSIONS**

The finding of herbicides in DeSoto Lake is not unusual. The lake receives direct input from at least three agricultural drains. Previous monitoring has consistently revealed these compounds in the surface waters of this lake. The presence of atrazine residual compounds indicates that atrazine is continually in the system and is breaking down as it ages.

The presence of herbicides within Young's Ditch, an agricultural drain, is likewise not unexpected. However, the detection of atrazine in Marquardt Pond during 1994 was unanticipated. The source of this small amount of herbicide was undetermined, however atrazine has repeatedly been detected in rainwater and this may account for its presence in the control pond.

Concentrations of herbicides detected during this sampling period, except for one sample taken directly from a drainage ditch, were below those detected in past years. This may be due to dilution of the chemicals, as 1993 was a year of record flooding throughout the state of Iowa.

Comparisons of the herbicide concentrations detected, to literature values and EPA criteria, indicate that these chemicals are not present in concentrations which would directly impact fish and wildlife resources.

There does appear to be a suppression of algal productivity related to the concentrations of herbicides. This suppression of algae may reduce the possibility of fish kills through crashes of algal blooms. However, the reduction of algal productivity may also allow nutrient levels to remain slightly elevated, thereby potentially increasing the natural eutrophication process of the lake.

The presence of agricultural chemicals is not a natural occurrence and steps should be taken to eliminate their presence from the surface waters of the refuge.

## **RECOMMENDATIONS**

The refuge should establish a periodic water quality monitoring program and continue to record pesticide concentrations in the lake.

Refuge management should work with off-refuge agricultural producers to establish buffer strips along the drainage ditches feeding onto refuge lands. Alternatively, the refuge may wish to consider buying permanent easements along the drainage ditches.

Should buffer strips or easements not be appropriate, the establishment of permanent treatment wetlands along the drainages could serve as a sink area to prevent agricultural chemicals from reaching the surface waters of the refuge.

In the event of any future fish kills or algae crashes, water samples should be taken immediately and submitted for herbicide and insecticide analysis. If a particular agent is suspect, it may also be beneficial to submit tissue samples.

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### **Explanation of Site Codes:**

The first two letters designate the sample area,  
DL = DeSoto Lake; CT = Marquardt Pond; YD = Young's Ditch

The third letter designates the sample month,  
J = June; Y = July; A = August; S = September

The fourth letter designates the type of sample,  
B = baseline; R = rainfall

The first number designates the sampling run,  
i.e. first sample of the month, second sample of the month (and type)

The last digit designates which site was sampled

Appendix A.  
Water Quality Results  
DeSoto Lake

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**Table 1. 1992 herbicide concentrations in DeSoto Lake, DeSoto National Wildlife Refuge ( $\mu\text{g/L}$ )**

June 6, 1992					
Herbicide	Rand's Ditch	Young's Ditch	Brown's Ditch	Lake #1	Lake #2
Atrazine	0.21	0.35	no data	1.60	1.60
Bladex	0.23	<0.1	no data	2.20	2.10
Dual	2.20	0.13	no data	0.37	0.33
Lasso	<0.1	<0.1	no data	<0.1	<0.1
Sencor	<0.1	<0.1	no data	<0.1	<0.1
Sutan	<0.1	<0.1	no data	<0.1	<0.1
Treflan	<0.1	<0.1	no data	<0.1	<0.1
July 2, 1992					
Herbicide	Rand's Ditch	Young's Ditch	Brown's Ditch	Lake #1	Lake #2
Atrazine	29.00	1.40	0.45	1.40	1.50
Bladex	0.23	2.00	0.19	1.90	2.20
Dual	49.00	0.32	0.93	0.24	0.26
Lasso	<0.3	<0.1	0.15	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	0.10	<0.1	<0.1	<0.1	<0.1
July 30, 1992					
Herbicide	Rand's Ditch	Young's Ditch	Brown's Ditch	Lake #1	Lake #2
Atrazine	0.25	2.90	3.40	1.40	1.40
Bladex	0.10	<0.1	0.66	1.70	1.80
Dual	0.83	4.10	1.80	0.18	0.16
Lasso	<0.1	0.21	0.21	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1
September 16, 1992					
Herbicide	Rand's Ditch	Young's Ditch	Brown's Ditch	Lake #1	Lake #2
Atrazine	0.14	1.50	1.20	1.30	1.40
Bladex	<0.1	<0.1	1.40	1.40	1.60
Dual	0.25	1.20	<0.1	<0.1	<0.1
Lasso	<0.1	<0.1	<0.1	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1

Water quality analyses, DeSoto Lake, DeSoto National Wildlife Refuge, 1993 ( $\mu\text{g/L}$  unless otherwise noted)

	DLJB-11	DLJB-14	DLJR-11	DLJR-14	DLYB-11	DLYB-14	DLYB-21	DLYB-24	DLYR-11	DLYR-14	DLAB-11	DLAB-14	DLSB-11	DLSB-14
Atrazine	2.2	2.1	2.3	1.8	2.3	2.4	2.0	2.1	1.7	1.8	1.2	1.9	1.46	1.4
Bladex	2.9	2.0	2.6	2.2	2.2	2.2	2.0	2.2	2.0	2.2	1.2	2.0	1.3	1.3
Dual	1.8	0.56	0.55	0.56	0.44	0.43	0.32	0.34	0.42	0.45	0.15	0.26	0.14	0.15
Lasso	1.7	0.77	0.45	0.46	0.22	0.25	0.16	0.17	0.30	0.30	<0.1	<0.1	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Desethyl atrazine <sup>1</sup>	0.31	0.24	0.26	0.28	0.43	0.37	0.38	0.40	0.24	0.25	0.93	0.58	0.26	0.31
Desisopropyl atrazine <sup>1</sup>	ND	ND	ND	ND	0.31	0.28	0.30	0.30	ND	ND	0.28	0.41	0.32	0.25
Chlorophyll a	16	15	15	12	61	47	66	76	50	63	101	117	150	191
Corrected chlorophyll a	3	11	<1	<1	56	35	48	75	49	62	93	112	146	177
Organic N (mg/L)	1.2	1.0	<0.1	1.21	1.21	1.41	1.41	1.21	0.41	0.8	1.8	1.6	2.8	2.6
Ammonia Nitrogen mg/L	0.3	0.3	0.2	0.3	0.2	0.1	0.1	0.4	0.4	0.2	0.3	0.2	0.2	0.3
Total Phosphate mg/L	0.3	0.2	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.1	0.2	0.1
Total Potassium mg/L	7.7	7.6	8.1	8.0	7.0	7.1	7.1	7.6	8.3	7.9	8.1	8.1	8.9	8.9
pH	7.6	8.5	9.4	9.8	8.6	8.6	10.0	10.1	10.7	10.6	8.48	8.7	8.9	9.0
Dissolved oxygen (mg/l) <sup>1</sup>	4.6	6.6	8.5	8.5	6.7	7.2	7.3	6.9	9.6	8.7	8.3	10.2	7.8	8.8
Water temperature (°C) <sup>1</sup>	21	22	25.5	24.5	25	25	25	25	27	27	26.3	26.6	20.5	20.3
Secchi reading (meters)	7.7	7.6	8.1	8.0	7.0	7.1	7.7	7.6	8.3	7.9	0.4	0.4	0.3	0.25

Desethyl atrazine and desisopropyl atrazine are breakdown compounds of the herbicide atrazine.  
Dissolved oxygen and water temperature readings were recorded at mid-water column.

TABLE 3. Water quality analyses, DeSoto Lake, DeSoto National Wildlife Refuge, 1994 ( $\mu\text{g/L}$ unless otherwise noted)										
	DLJB-11*	DLJB-14*	DLJR-11*	DLJR-14*	DLJB-21**	DLJB-24**	DLYB-11	DLYB-14	DLYR-11	DLYR-14
Atrazine	1.3	1.1	1.3	1.2	1.4	1.4	1.2	1.3	1.3	1.3
Bladex	0.84	0.68	0.75	0.77	1.1	1.1	0.83	0.88	0.99	1.1
Dual	0.42	0.34	0.85	.52	0.57	0.52	0.33	0.35	0.52	0.51
Lasso	0.18	0.15	0.12	.11	0.12	0.15	<0.1	<0.1	0.11	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Desethyl atrazine	0.17	0.12	0.18	0.17	0.20	0.20	0.18	0.15	0.15	0.15
Chlorophyll a	40	43	6	10	7	10	96	97	#	#
corrected chlorophyll a	34	38	<1	<1	<1	<1	93	82	#	#
Nitrate + Nitrite Nitrogen as N mg/L	0.1	0.1	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonia Nitrogen mg/L	0.2	0.3	0.2	0.5	1.1	0.3	0.5	0.3	0.3	0.2
Organic Nitrogen mg/L	0.6	0.6	0.9	1.0	<0.1	0.9	no data	no data	1.3	1.3
Total Phosphate mg/L	0.2	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.2
Total Potassium mg/L	7.6	7.1	8.0	7.5	7.6	7.5	7.4	6.9	8.2	8.2
pH	8.3	8.3	8.4	8.35	8.53	8.5	8.76	8.87	8.57	8.56
Dissolved oxygen (mg/l)	7	7.5	7.3	6.6	9.6	8.4	no data <sup>1</sup>	no data <sup>1</sup>	7.5	6.6
Water temperature ( $^{\circ}\text{C}$ )	26	26	26	26	26	26.25	no data <sup>1</sup>	no data <sup>1</sup>	27	27
Secchi reading (meters)	.67	no data	.67	1.1	.5	.5	.5	.33	.5	.5

\* these samples were taken off of Brown's Ditch instead of Young's Ditch

# chlorophyll analysis not completed due to laboratory error

<sup>1</sup> equipment failure

**TABLE 3 (continued). Water quality analyses, DeSoto Lake, DeSoto National Wildlife Refuge, 1994 ( $\mu\text{g/L}$  unless otherwise noted)**

	DLYB-21	DLYB-24	DLAB-11	DLAB-14	DLAB-21	DLAB-24	DLSB-11	DLSB-14	DLSB-21	DLSB-24
Atrazine	1.3	1.3	0.96	1.0	1.0	1.1	1.0	1.0	0.92	0.89
Bladex	1.1	0.95	.69	0.71	0.62	0.67	0.69	0.73	0.56	0.55
Dual	0.43	0.39	0.24	0.24	0.17	0.18	0.10	0.11	<0.1	<0.1
Lasso	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Desethyl atrazine	0.23	0.21	0.15	0.18	0.17	0.17	0.19	0.20	0.16	0.16
Chlorophyll a	113	88	201	177	159	176	194	191	173	143
Corrected chlorophyll a	96	75	186	170	149	167	186	165	164	139
Nitrate + Nitrite Nitrogen as N mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
Ammonia Nitrogen mg/L	<0.1	<0.1	0.3	0.1	0.2	0.2	0.1	<0.1	0.5	0.6
Organic Nitrogen mg/L	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
Total Phosphate mg/L	<0.1	<0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.2	0.3
Total Potassium mg/L	7.1	7.8	8.0	1.5	7.2	7.2	7.8	7.7	7.2	7.6
pH	8.46	8.69	8.43	8.47	9.02	8.91	8.64	8.8	8.51	8.6
Dissolved oxygen (mg/l)	8.1	8.2	8.6	9.7	12.1	10.8	11.6	8.9	12	8.6
Water temperature ( $^{\circ}\text{C}$ )	26.5	26	27	27	26	25.4	24	22	20	18
Secchi reading (meters)	.4	.5	.3	.3	.3	.3	.3	.3	.3	.3

**Appendix B:**  
**Water Quality Results**  
**Marquardt Pond**

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TABLE 4. Water quality analyses, Marquardt Pond, DeSoto National Wildlife Refuge, 1993 (reported as $\mu\text{g/L}$ unless otherwise noted)								
	CTJB-11	CTJB-14	CTYB-11	CTYB-14	CTAB-11	CTAB-14	CTSB-11	CTSB-14
Atrazine	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bladex	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dual	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lasso	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlorophyll a	3	2	8	22	9	7	72	70
Corrected chlorophyll a	1	<1	4	19	5	4	48	48
Organic Nitrogen (mg/L)	0.9	0.7	0.9	1.4	0.8	0.8	1.7	1.4
Ammonia Nitrogen (mg/L)	<0.1	<0.1	<0.1	<0.1	0.2	0.2	0.2	0.2
Total Phosphate (mg/L)	0.2	0.2	<0.1	<0.1	<0.1	<0.1	0.2	0.2
Total Potassium (mg/L)	2.9	9.1	9.3	9.4	9.9	9.8	11	11
pH	8.6	8.9	10.5	10.8	8.2	8.15	7.9	no data
Dissolved oxygen (mg/l)	11.0	7.5	7.4	0.4	0.3	0.4	3.6	0.3
Water temperature ( $^{\circ}\text{C}$ )	24	22	24.8	23.2	19.	23	22	21
Secchi reading (meters)	2	2.8	1.2	1.1	1.4	1.2	1.7	no data

<b>TABLE 5. Water quality analyses, Marquardt Pond, DeSoto National Wildlife Refuge, 1994 (<math>\mu\text{g/L}</math> unless otherwise noted)</b>									
	CTJB-11	CTJB-14	CTJR-11	CTJR-14	CTJB-21	CTJB-24	CTYB-11	CTYB-14	CTYB-21
Atrazine	0.10	0.1	0.10	0.10	<0.1	0.11	<0.1	<0.1	0.10
Bladex	0.11	0.10	0.1	0.1	0.1	0.12	<0.1	<0.1	<0.1
Dual	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lasso	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlorophyll a	1	1	2	1	<1	<1	27	8	30
Corrected chlorophyll a	<1	<1	<1	<1	<1	<1	18	6	28
Nitrate + Nitrite Nitrogen as N (mg/L)	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonia Nitrogen mg/L	0.6	0.9	0.3	0.2	0.4	0.4	0.4	0.7	<0.1
Organic Nitrogen mg/L	0.2	0.5	0.6	0.8	0.2	0.6	no data	no data	no data
Total Phosphate	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Potassium	8.9	9.0	9.2	9.2	9.4	9.3	9.2	9.2	9.2
pH	8.8	no data	9.4	9.4	9.1	9.61	9.73	9.75	9.65
Dissolved oxygen (mg/l)	7	no data	4.8	3.6	1.9	8.0	no data <sup>2</sup>	no data <sup>2</sup>	6.5
Water temperature ( $^{\circ}\text{C}$ )	24	no data	26	25	25	27	no data <sup>2</sup>	no data <sup>2</sup>	25.5
Secchi reading (meters)	2.4	no data	3.5	no data <sup>1</sup>	2.75	no data <sup>1</sup>	1.5	1.5	1.5

<sup>1</sup> vegetation too thick to drop Secchi disk

<sup>2</sup> equipment failure

**TABLE 5 (continued). Water quality analyses, Marquardt Pond, DeSoto National Wildlife Refuge, 1994 ( $\mu\text{g/L}$  unless otherwise noted)**

	CTYB-24	CTAB-11	CTAB-14	CTAB-21	CTAB-24	CTSB-11	CTSB-14	CTSB-21	CTSB-24
Atrazine	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bladex	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dual	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lasso	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlorophyll a	15	61	52	37	24	10	15	19	21
Corrected chlorophyll a	9	51	49	37	24	5	14	18	15
Nitrate + Nitrite Nitrogen as N (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
Ammonia Nitrogen mg/L	<0.1	0.2	0.2	0.1	0.1	0.2	<0.1	0.2	0.2
Organic Nitrogen mg/L	no data	no data	no data	no data	no data	no data	no data	no data	no data
Total Phosphate	<0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1
Total Potassium	9.1	2.8	1.9	11	10	11	9.8	10	10
pH	9.7	9.4	9.36	9.08	9.02	9.1	8.71	8.03	8.38
Dissolved oxygen (mg/l)	7.6	5.5	5.1	.90*	.90**	6.1	7.5	6.0	8.8
Water temperature ( $^{\circ}\text{C}$ )	26.5	26.0	26.1	24.1	25.1	22.2	23	17.1	18.1
Secchi reading (meters)	1.75	1.0	1.0	1.0	1.0	1.75	1.0	1.0	1.0

\* surface DO was 8.1

\*\* surface DO was 8.0

Appendix C:  
Water Quality Results  
Young Ditch

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**TABLE 6. Water quality analyses, Young's Ditch, DeSoto National Wildlife Refuge, 1994 ( $\mu\text{g/L}$  unless otherwise noted)**

	YDJR-11	YDYR-11	YDYB-11	YDYB-21*	YDAB-11	YDAB-21	YDSB-11
Atrazine	5.0	1.2	1.3	0.68	0.96	0.99	0.73
Bladex	2.0	0.20	<0.1	<0.1	0.34	0.58	0.42
Dual	11	4.0	1.0	0.84	1.0	0.20	<0.1
Lasso	1.1	0.13	0.22	0.45	0.10	<0.1	<0.1
Sencor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sutan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Treflan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Desethyl atrazine	1.4	0.1	0.54	0.23	0.33	0.19	0.15
Desisopropyl atrazine	0.31	0.31	not detected	not detected	not detected	not detected	not detected
Chlorophyll a	36	**	9	58	151	65	51
Corrected chlorophyll a	6	**	9	42	129	58	35
Nitrate + Nitrogen as N (mg/L)	6.4	0.6	<0.1	<0.1	0.1	<0.1	0.2
Ammonia Nitrogen mg/L	0.6	0.3	<0.1	0.3	0.3	0.3	0.3
Organic Nitrogen mg/L	2.0	1.3	no data	no data	no data	no data	no data
Total Phosphate	0.6	0.6	0.1	0.2	0.3	0.2	0.2
Total Potassium	11	11	8.4	6.4	12	8.7	8.4
pH <sup>1</sup>	7.53	7.49	8.16	8.01	7.82	7.43	7.5
Dissolved oxygen (mg/l) <sup>1</sup>	5.4	8.7	no data <sup>2</sup>	7.2	7.1	8.4	3.2
Water temperature (°C) <sup>1</sup>	21	25	no data <sup>2</sup>	23	24	26.1	16.9

\* due to breakage during shipping, herbicide sample was collected 2 days after the samples submitted for inorganic chemistry.

\*\* chlorophyll analysis not conducted due to laboratory error

<sup>1</sup> readings taken from pail of water pulled from ditch

<sup>2</sup> equipment failure

**Appendix D:**

**Selenastrum toxicity test results  
from Iowa Hygienic Laboratory**

Filtered Weight of Algae In Each Flask - by Treatment

Treatment	Flask Number	Volume Filtered (mls)	Filter Number	Tare Weight (mg)	Ending Weight (mg)	Change in Weight (mg)	Total Weight of Algae * (mg)
A + B	1-1	40	51	83.70	84.32	0.62	1.92
A + B	2-1	40	52	83.39	83.37	-0.02	1.28
A + B	3-1	40	53	83.70	84.17	0.47	1.77
A + B	4-1	40	54	84.00	84.93	0.93	2.23
A + B	5-1	40	55	83.82	85.23	1.41	2.71
A + B	1-2	40	56	83.40	83.84	0.44	1.74
A + B	2-2	40	43	83.96	84.00	0.04	1.34
A + B	3-2	40	44	83.94	83.95	0.01	1.31
A + B	4-2	40	45	83.69	83.78	0.09	1.39
A + B	5-2	40	42	83.77	85.06	1.29	2.59
B + D	1-1	40	13	83.93	85.32	1.39	2.69
B + D	2-1	40	14	83.90	84.35	0.45	1.75
B + D	3-1	40	15	83.61	84.01	0.40	1.70
B + D	4-1	40	16	83.87	83.58	-0.29	1.01
B + D	5-1	40	17	83.72	84.70	0.98	2.28
B + D	1-2	40	18	83.71	84.24	0.53	1.83
B + D	2-2	40	19	83.76	84.50	0.74	2.04
B + D	3-2	40	21	83.81	84.24	0.43	1.73
B + D	4-2	40	20	83.82	84.77	0.95	2.25
B + D	5-2	40	22	83.78	84.22	0.44	1.74
A + D	1-1	40	1	83.55	84.41	0.86	2.16
A + D	2-1	40	2	83.86	85.51	1.65	2.95
A + D	3-1	40	3	83.85	85.78	1.93	3.23
A + D	4-1	40	4	84.06	84.67	0.61	1.91
A + D	5-1	40	5	83.88	84.66	0.78	2.08
A + D	1-2	40	6	83.63	83.91	0.28	1.58
A + D	2-2	40	7	83.88	85.68	1.80	3.10

1993 Selenastrum toxicity test results (continued)

Treatment	Flask Number	Volume Filtered (mls)	Filter Number	Tare Weight (mg)	Ending Weight (mg)	Change in Weight (mg)	Total Weight of Algae * (mg)
A + D	3-2	40	8	83.87	84.01	0.14	1.44
A + D	4-2	40	9	83.89	85.07	1.18	2.48
A + D	5-2	40	10	83.72	84.11	0.39	1.69
A + B + D	1-1	40	57	83.32	83.93	0.61	1.91
A + B + D	2-1	40	58	83.54	83.59	0.05	1.35
A + B + D	3-1	40	59	83.76	83.98	0.22	1.52
A + B + D	4-1	40	60	83.60	82.93	-0.67	0.63
A + B + D	5-1	40	61	83.64	83.72	0.08	1.38
A + B + D	1-2	40	62	83.91	83.85	-0.06	1.24
A + B + D	2-2	40	63	83.61	84.91	1.30	2.60
A + B + D	3-2	40	64	83.60	83.65	0.05	1.35
A + B + D	4-2	40	65	83.80	84.12	0.32	1.62
A + B + D	5-2	40	48	83.69	85.34	1.65	2.95
Control	1-1	40	47	83.42	84.26	0.84	2.14
Control	2-1	40	23	83.84	84.45	0.61	1.91
Control	3-1	40	24	83.89	83.95	0.06	1.36
Control	4-1	40	34	83.75	84.20	0.45	1.75
Control	5-1	40	35	83.54	84.18	0.64	1.94
Control	1-2	40	36	83.69	84.21	0.52	1.82
Control	2-2	40	37	83.77	83.75	-0.02	1.28
Control	3-2	40	38	83.80	84.26	0.46	1.76
Control	4-2	40	39	83.74	84.58	0.84	2.14
Control	5-2	40	40	83.47	84.62	1.15	2.45

Filter Rinse	1	40	11	83.78	82.52	-1.26
Filter Rinse	2	40	12	83.75	82.45	-1.30
Filter Rinse	3	40	49	83.79	82.50	-1.29
Filter Rinse	4	40	50	83.62	82.29	-1.33
Filter Rinse	5	40	46	83.54	82.22	-1.32
Average filter weight loss (mg)						1.30

\* Total Weight of Algae Adjusted for Average Filter Weight Loss of .30 mg

## Filtered Weight of Algae In Each Flask - by Treatment

Treatment	Flask Number	Volume Filtered (ml)	Filter Number	Tare Weight (mg)	Ending Weight (mg)	Change in Weight (mg)	Total Weight of Algae (mg/40 ml)
A + B	1	40	11	84.06	105.45	21.39	20.91
A + B	2	20	12	84.06	90.89	6.83	13.18
A + B	3	20	13	84.00	93.92	9.92	19.36
A + B	4	20	14	84.11	94.12	10.01	19.54
A + B	5	20	15	84.17	95.60	11.43	22.38
A + B	6	20	16	84.04	88.70	4.66	8.84
A + B	7	20	17	84.19	90.83	6.64	12.80
A + B	8	20	18	84.25	89.34	5.09	9.70
A + B	9	20	19	83.94	88.01	4.07	7.66
A + B	10	20	20	84.16	88.71	4.55	8.62
B + D	1	20	31	84.03	91.06	7.03	13.58
B + D	2	20	32	84.06	88.75	4.69	8.90
B + D	3	20	33	83.97	93.19	9.22	17.96
B + D	4	20	34	83.96	88.54	4.58	8.68
B + D	5	20	35	83.90	89.59	5.69	10.90
B + D	6	20	36	84.09	92.60	8.51	16.54
B + D	7	20	37	84.12	88.89	4.77	9.06
B + D	8	20	38	83.99	93.09	9.10	17.72
B + D	9	20	39	83.79	89.55	5.76	11.04
B + D	10	20	40	84.06	89.78	5.72	10.96
A + D	1	20	21	84.04	89.02	4.98	9.48
A + D	2	20	22	84.00	88.78	4.78	9.08
A + D	3	20	23	83.94	89.49	5.55	10.62
A + D	4	20	24	83.97	90.33	6.36	12.24
A + D	5	20	25	84.17	88.23	4.06	7.64
A + D	6	20	26	84.24	93.23	8.99	17.50
A + D	7	20	27	84.00	89.07	5.07	9.66

1994 *Selenastrum* toxicity test results (continued)

Treatment	Flask Number	Volume Filtered (ml)	Filter Number	Tare Weight (mg)	Ending Weight (mg)	Change in Weight (mg)	Total Weight of Algae (mg/40 ml)
A + D	8	20	28	84.11	89.26	5.15	9.82
A + D	9	20	29	84.26	88.80	4.54	8.60
A + D	10	20	59	83.92	93.41	9.49	18.50
A + B + D	1	20	41	83.84	91.02	7.18	13.88
A + B + D	2	15	42	84.14	90.35	6.21	16.10
A + B + D	3	20	43	84.02	88.37	4.35	8.22
A + B + D	4	20	44	84.26	91.60	7.34	14.20
A + B + D	5	20	45	84.01	94.28	10.27	20.06
A + B + D	6	20	46	84.00	93.52	9.52	18.56
A + B + D	7	20	47	84.23	91.04	6.81	13.14
A + B + D	8	20	48	84.26	93.66	9.40	18.32
A + B + D	9	20	49	84.10	91.95	7.85	15.22
A + B + D	10	20	50	84.34	89.50	5.16	9.84
Control	1	40	1	83.94	101.03	17.09	16.61
Control	2	20	2	84.13	93.99	9.86	19.24
Control	3	20	3	83.75	89.52	5.77	11.06
Control	4	20	4	83.96	89.85	5.89	11.30
Control	5	20	5	83.98	91.50	7.52	14.56
Control **	6	20	60	83.91	93.45	9.54	18.60
Control	7	20	7	83.98	97.78	13.80	27.12
Control	8	20	8	83.87	94.84	10.97	21.46
Control	9	20	9	83.87	96.81	12.94	25.40
Control	10	20	10	83.97	89.14	5.17	9.86

Blank	1	20	51	83.92	83.66	0.52
Blank	2	20	52	84.16	83.91	0.50
Blank	3	20	53	84.05	83.78	0.54
Blank	4	20	54	83.91	83.66	0.50
Blank	5	20	55	84.46	84.18	0.56
Blank	6	40	56	84.27	83.80	0.47
Blank	7	40	57	84.11	83.83	0.28
Average filter weight loss (mg/L)						0.48

\*\*Some algae was lost on the filter cover (paper filter).